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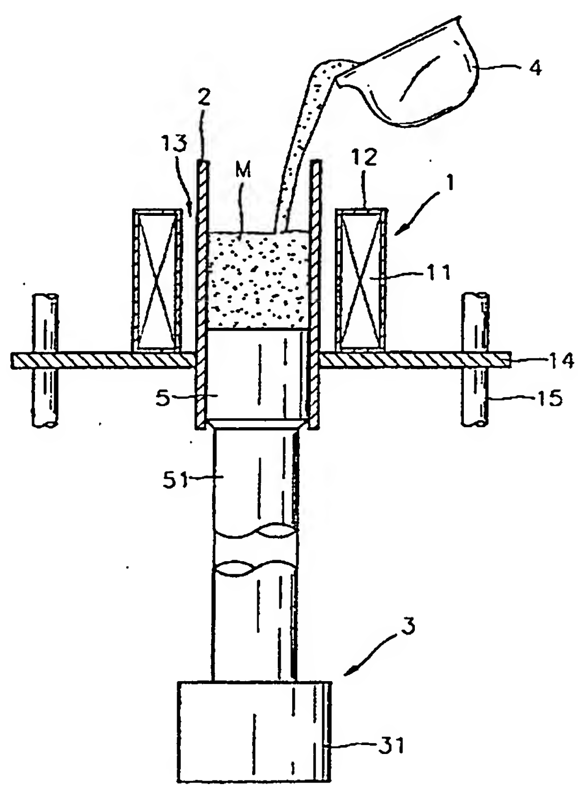
(54) Apparatus for manufacturing semi-solid metallic slurry

(57) Provided is an apparatus for manufacturing a high-quality semi-solid metallic slurry containing fine, uniform spherical particles that can be readily and conveniently applied to a subsequent process, with improvements in energy efficiency and mechanical properties, cost reduction, convenience of casting, shorter manufacturing time, and easy discharge. The apparatus includes at least one sleeve for receiving molten metals in liquid state; a stirring unit for applying an electromagnetic field to the molten metals in the sleeve; at least one plunger for defining the bottom of a space where the molten metals are loaded, the plunger being inserted into an end of the sleeve; and a driving unit for driving the plunger upward and downward.

FIG. 2



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Description

BACKGROUND OF THE INVENTION

[0001] This application claims the priority of Korean Patent Application No. 2003-25998, filed on April 24, 2003, in the Korean Intellectual Property Office, the disclosure of which is incorporated herein in its entirety by reference.

1. Field of the Invention

[0002] The present invention relates to an apparatus for manufacturing a semi-solid metallic slurry, and more particularly, to an apparatus for manufacturing a semi-solid metallic slurry in a combined solid and liquid state, containing fine, uniform spherical particles.

2. Description of the Related Art

[0003] Semi-solid metallic slurries refer to metallic materials, in a combined solid and liquid phase, which are intermediates manufactured by thixocasting, also expressed as rheocasting/thixocasting. Semi-solid metallic slurries consist of spherical solid particles suspended in a liquid phase in an appropriate ratio at temperature ranges of a semi-solid state, and thus, they can be transformed even by a little force due to their thixotropic properties and can be easily cast like a liquid due to their high fluidity. Rheocasting refers to a process of manufacturing billets or final products from metallic slurries with a predetermined viscosity through casting or forging. Thixocasting refers to a process involving reheating billets, manufactured through rheocasting, back into semi-molten metallic slurries and casting or forging the metallic slurries to manufacture final products.

[0004] Such rheocasting/thixocasting is more advantageous than general forming processes using molten metals, such as casting or forging. Because semi-solid/semi-molten metallic slurries used in rheocasting/thixocasting have fluidity at a lower temperature than molten metals, it is possible to lower the die casting temperature, thereby ensuring an extended lifespan of the die. In addition, when semi-solid/semi-molten metallic slurries are extruded through a cylinder, turbulence is less likely to occur, and thus less air is incorporated during casting. Therefore, the formation of air pockets in final products is prevented. Besides, the use of semi-solid/semi-molten metallic slurries leads to reduced shrinkage during solidification, improved working efficiency, mechanical properties, and anti-corrosion, and lightweight products. Therefore, such semi-solid/semi-molten metallic slurries can be used as new materials in the fields of automobiles, airplanes, and electrical, electronic information communications equipment.

[0005] As described above, semi-solid metallic slurries are used both in rheocasting and thixocasting. In detail, semi-solid slurries solidified from molten metals by a predetermined method are used in rheocasting, and semi-molten slurries obtained by reheating solid billets are used in thixocasting. Throughout the specification of the present invention, the term, "semi-solid metallic slurries" means metallic slurries in a combined solid and liquid state at a temperature range, between the liquidus temperature and the solidus temperature of the metals, which can be manufactured by rheocasting through solidification of molten metals.

[0006] In conventional rheocasting, molten metals are stirred at a temperature of lower than the liquidus temperature while cooling, to break up dendritic structures into spherical particles suitable for rheocasting, for example, by mechanical stirring, electromagnetic stirring, gas bubbling, low-frequency, high-frequency, or electromagnetic wave vibration, electrical shock agitation, etc.

[0007] By way of example, U.S. Patent No. 3,948,650 discloses a method and apparatus for manufacturing a liquid-solid mixture. In this method, molten metals are vigorously stirred while cooled for solidification. A semi-solid metallic slurry manufacturing apparatus disclosed in this patent uses a stirrer to induce flow of the solid-liquid mixture having a predetermined viscosity to break up dendritic crystalline structures or disperse broken dendritic crystalline structures in the liquid-solid mixture. In this method, dendritic crystalline structures formed during cooling are broken up and used as nuclei for spherical particles. However, due to generation of latent heat of solidification at the early stage of cooling, the method causes problems of low cooling rate, manufacturing time increase, uneven temperature distribution in a mixing vessel, and non-uniform crystalline structure. Mechanical stirring applied in the semi-solid metallic slurry manufacturing apparatus inherently leads to non-uniform temperature distribution in the mixing vessel. In addition, because the apparatus is operated in a chamber, it is difficult to continuously perform a subsequent process.

[0008] U.S. Patent No. 4,465,118 discloses a method and apparatus for manufacturing semi-solid alloy slurries. This apparatus includes a coiled electromagnetic field application unit, a cooling manifold, and a die, which are sequentially formed inward, wherein molten metals are continuously loaded down into the vessel, and cooling water is flowed through the cooling manifold to cool the outer wall of the die. In manufacturing semi-solid alloy slurries, molten metals are injected through a top opening of the die and cooled by the cooling manifold, thereby resulting in a solidification zone within the die. When a magnetic field is applied by the electromagnetic field application unit, cooling is allowed to break up dendritic crystalline structures formed in the solidification zone. Finally, ingots are formed from the slurries and then pulled through the lower end of the apparatus. The basic technical idea of this method and apparatus is to break up dendritic crystalline structures after solidification by applying vibration. However, many problems arise with this method, such as complicated processing

and non-uniform particle structure. In the manufacturing apparatus, since molten metals are continuously supplied to grow ingots, it is difficult to control the states of the metal ingots and the overall process. Moreover, prior to applying an electromagnetic field, the die is cooled using water, so that a great temperature difference exists between the peripheral and core regions of the die.

[0009] Other types of rheocasting/thixocasting known in the art are described later. However, all of the methods are based on the technical idea of breaking up dendritic crystalline structures after formation, to generate nuclei of spherical particles. Therefore, problems arise, such as those described in conjunction with the above patents.

[0010] U. S. Patent No. 4,694,881 discloses a method for manufacturing thixotropic materials. In this method, an alloy is heated to a temperature at which all metallic components of the alloy are present in a liquid phase, and the resulting molten metals are cooled to a temperature between their liquidus and solidus temperatures. Then, the molten metals are subjected to a shearing force in an amount sufficient to break up dendritic structures formed during the cooling of the molten metals to thereby manufacture the thixotropic materials.

[0011] Japanese Patent Application Laid-open Publication No. Hei. 11-33692 discloses a method for manufacturing metallic slurries for rheocasting. In this method, molten metals are supplied into a vessel at a temperature near their liquidus temperature or of 50°C above their liquidus temperature. Next, when at least a portion of the molten metals reaches a temperature lower than the liquidus temperature, i.e., at least a portion of the molten metals begins with cooling below their liquidus temperature, the molten metals are subjected to a force, for example, ultrasonic vibration. Finally, the molten metals are slowly cooled into the metallic slurries containing spherical particles. This method also uses a physical force, such as ultrasonic vibration, to break up the dendrites grown at the early stage of solidification. In this regard, if the casting temperature is greater than the liquidus temperature, it is difficult to form spherical particle structures and to rapidly cool the molten metals. Furthermore, this method leads to non-uniform surface and core structures.

[0012] Japanese Patent Application Laid-open Publication No. Hei. 10-128516 discloses a casting method of thixotropic metals. This method involves loading molten metals into a vessel and vibrating the molten metals using a vibrating bar dipped in the molten metals to directly transfer its vibrating force to the molten metals. After forming a semi-solid and semi-liquid molten alloy, which contains nuclei, at a temperature range lower than its liquidus temperature, the molten alloy is cooled to a temperature at which it has a predetermined liquid fraction and then left stand from 30 seconds to 60 minutes to allow the nuclei to grow, thereby resulting in thixotropic metals. However, this method provides relatively large particles of about 100μm and takes a considerably long processing time, and cannot be performed in a vessel larger than a predetermined size.

[0013] U.S. Patent No. 6,432,160 discloses a method for making thixotropic metal slurries. This method involves simultaneously controlling the cooling and the stirring of molten metals to form the thixotropic metal slurries. In detail, after loading molten metals into a mixing vessel, a stator assembly positioned around the mixing vessel is operated to generate a magnetomotive force sufficient to rapidly stir the molten metals in the vessel. Next, the molten metals are rapidly cooled by means of a thermal jacket, equipped around the mixing vessel, for precise temperature control of the mixing vessel and the molten metals. During cooling, the molten metals are continuously stirred in a manner such that when the solid fraction of the molten metals is low, a high stirring rate is provided, and when the solid fraction increases, a greater magnetomotive force is applied.

[0014] Most of the aforementioned conventional methods and apparatuses for manufacturing semi-solid metal slurries use shear force to break dendritic structures into spherical structures during a cooling process. Since a force such as vibration is applied after at least a portion of the molten metals is cooled below their liquidus temperature, latent heat is generated due to the formation of initial solidification layers. As a result, there are many disadvantages such as reduced cooling rate and increased manufacturing time. In addition, due to a non-uniform temperature between the inner wall and the center of the vessel, it is difficult to form fine, uniform spherical metal particles. Therefore, this structural non-uniformity of metal particles will be greater if the temperature of the molten metals loaded into the vessel is not controlled.

[0015] In order to solve these problems, the present inventor filed Korean Patent Application No. 2003-13517, titled "Method and apparatus for manufacturing semi-solid metallic slurry".

SUMMARY OF THE INVENTION

[0016] The present invention provides an apparatus for manufacturing a semi-solid metallic slurry containing fine, uniform spherical particles, with improvements in energy efficiency and mechanical properties, cost reduction, convenience of casting, and shorter manufacturing time.

[0017] The present invention also provides an apparatus for manufacturing a high-quality semi-solid metallic slurry within a short period of time, which can be readily and conveniently applied to a subsequent process.

[0018] The present invention also provides an apparatus for manufacturing and discharging a high-quality semi-solid metallic slurry in a convenient manner.

[0019] According to an aspect of the present invention, there is provided an apparatus for manufacturing a semi-solid metallic slurry, the apparatus comprising: at least one sleeve for receiving molten metals in liquid

state; a stirring unit for applying an electromagnetic field to the molten metals in the sleeve; at least one plunger for defining the bottom of a space where the molten metals are loaded, the plunger being inserted into an end of the sleeve; and a driving unit for driving the plunger upward and downward.

[0020] According to specific embodiments of the present invention, the stirring unit may apply the electromagnetic field to the sleeve prior to loading the molten metals into the sleeve. Alternatively, the stirring unit may apply the electromagnetic field to the sleeve simultaneously with or in the middle of loading the molten metals into the sleeve.

[0021] The stirring unit may apply the electromagnetic field to the sleeve until the loaded molten metals have a solid fraction of 0.001-0.7, preferably 0.001-0.4, and more preferably 0.001-0.1.

[0022] The molten metals in the sleeve may be cooled until they have a solid fraction of 0.1-0.7.

[0023] The apparatus may further comprise a temperature control element that is installed around the sleeve to cool the molten metals. The temperature control element may comprise at least one of a cooler and a heater that are installed around the sleeve. The temperature control element may cool the molten metals in the sleeve at a rate of 0.2-5.0°C/sec, preferably, 0.2-2.0°C/sec.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] The above and other features and advantages of the present invention will become more apparent by describing in detail exemplary embodiments thereof with reference to the attached drawings in which:

FIG. 1 is a graph of the temperature profile applied to an apparatus for manufacturing a semi-solid metallic slurry according to the present invention;

FIG. 2 illustrates the structure of an apparatus for manufacturing a semi-solid metallic slurry according to an embodiment of the present invention;

FIG. 3 is a sectional view of an example of a sleeve used in a semi-solid metallic slurry manufacturing apparatus according to the present invention;

FIG. 4 illustrates a semi-solid metallic slurry manufactured using the apparatus shown in FIG. 2; and

FIG. 5 illustrates a discharge of a semi-solid metallic slurry manufactured using the apparatus shown in FIG. 2.

DETAILED DESCRIPTION OF THE INVENTION

[0025] Hereinafter, the present invention will be described in detail with reference to the accompanying drawings.

[0026] First, the method for manufacturing a semi-solid metallic slurry by the apparatus of the present invention will be described with reference to FIG. 1.

[0027] Unlike the aforementioned conventional techniques, a method for manufacturing a semi-solid metallic slurry using the apparatus of the present invention involves stirring molten metals by applying an electromagnetic field prior to the completion of loading the molten metals into a sleeve. In other words, electromagnetic stirring is performed prior to, simultaneously with, or in the middle of loading the molten metals into the sleeve, to prevent the formation of dendritic structures. The stirring process may be performed using ultrasonic waves instead of the electromagnetic field.

[0028] First, after an electromagnetic field is applied to the at least one sleeve surrounded by the stirring unit, molten metals are loaded into the sleeve. In this case, the electromagnetic field is applied in an intensity sufficient to stir the molten metals.

[0029] As shown in FIG. 1, molten metals are loaded into the sleeve at a temperature Tp. As described above, an electromagnetic field may be applied to the sleeve prior to loading molten metals into the sleeve. However, the present invention is not limited to this, and electromagnetic stirring may be performed simultaneously with or in the middle of loading the molten metals into the sleeve.

[0030] Due to the electromagnetic stirring performed prior to the completion of loading molten metals into the sleeve, the molten metals do not grow into dendritic structures near the inner wall of the low temperature sleeve at the early stage of solidification. That is, numerous micronuclei are concurrently generated throughout the sleeve because all molten metals are rapidly cooled to a temperature lower than their liquidus temperature.

[0031] Applying an electromagnetic field to the sleeve prior to or simultaneously with loading molten metal into the sleeve leads to active stirring of the molten metals in the center and the inner wall regions of the sleeve and rapid heat transfer throughout the sleeve. Therefore, at the early stage of cooling, the formation of solidification layers near the inner wall of the sleeve is prevented. In addition, such active stirring of the molten metals induces smooth convection heat transfer between the higher temperature molten metals and the lower temperature inner sleeve wall. Therefore, the molten metals can be rapidly cooled. Due to the electromagnetic stirring, particles contained in the molten metals scatter upon loading the molten metals into the sleeve and are dispersed throughout the sleeve as nuclei, so that only a minor temperature difference occurs in the sleeve during cooling. However, in conventional techniques, when the molten metals contact with a low temperature inner vessel wall, solidification layers are formed near the inner wall of the vessel. Dentritic crystals are formed from the solidification layers.

[0032] The principles of the present invention will become more apparent when described in connection with latent heat of solidification. Molten metals are not solidified near the inner sleeve wall at the early stage of cooling, and no latent heat of solidification is generated. Ac-

cordingly, only the specific heat of the molten metals, which corresponds to about 1/400 of the latent heat of solidification, is required to cool the molten metals. Therefore, dendrites, which are generated frequently near the inner sleeve wall at the early stage of cooling when using conventional methods, are not formed. All molten metals in the sleeve can be uniformly cooled within merely about 1-10 seconds from the loading of the molten metals. As a result, numerous nuclei are created and uniformly dispersed throughout all molten metals in the sleeve. The increased nuclei density reduces the distance between the nuclei, and spherical particles instead of dendritic particles are formed.

[0033] The same effects can even be achieved even when an electromagnetic field is applied in the middle of loading the molten metals into the sleeve. In other words, solidification layers are hardly formed near the inner sleeve wall even when electromagnetic stirring begins in the middle of loading the molten metals into the sleeve.

[0034] It is preferable to limit the loading temperature, Tp, of the molten metals to a range from their liquidus temperature to 100°C above the liquidus temperature (melt superheat = 0~100°C). According to the present invention, since the entire sleeve containing the molten metals is uniformly cooled, there is no need to cool the molten metals to near their liquidus temperature. Therefore, it is possible to load the molten metals into the sleeve at a temperature of 100°C above their liquidus temperature.

[0035] On the other hand, after the completion of loading molten metals into a vessel in one conventional method, an electromagnetic field is applied to a vessel when a portion of the molten metals reaches below their liquidus temperature. Accordingly, latent heat is generated due to the formation of solidification layers near the inner wall of the vessel at the early stage of cooling. Because the latent heat of solidification is about 400 times greater than the specific heat of the molten metals, significant time is required to drop the temperature of the entire molten metals below their liquidus temperature. Therefore, in such a conventional method, the molten metals are generally loaded into a vessel after the molten metals are cooled to a temperature near their liquidus temperature or a temperature of 50°C above their liquidus temperature.

[0036] According to the present invention, the electromagnetic stirring may be stopped at any point after at least a portion of the molten metals in the sleeve reaches a temperature lower than the liquidus temperature T_l, i.e., after accomplishing nucleation for a solid fraction of a predetermined amount such as about 0.001, as illustrated in FIG. 1. That is, an electromagnetic field may be applied to the molten metals in the sleeve throughout the cooling process of the molten metals and then stopped prior to a subsequent forming process such as die casting or hot forging. This is because, once nuclei are distributed uniformly throughout the sleeve, even at the time of growth of crystalline particles from the nuclei, properties of the metallic slurry are not affected by the electromagnetic stirring. Therefore, the electromagnetic stirring can be carried out until a solid fraction of the molten metals is 0.001-0.7. However, in view of energy efficiency, it is preferable to carry out the electromagnetic stirring until a solid fraction of the molten metals is in a range of 0.001-0.4, and more preferably, 0.001-0.1.

[0037] After the electromagnetic stirring is completed, the metallic slurry is discharged from the sleeve for a continuous subsequent process, for example, die casting, hot forging, and billet formation.

[0038] After an electromagnetic field is applied and prior to completion of loading the molten metals into the sleeve to form uniformly distributed nuclei, the sleeve is cooled to facilitate the growth of the nuclei. This cooling process may be performed simultaneously with loading the molten metals into the sleeve.

[0039] As described above, an electromagnetic field may be continuously applied during the cooling process. In other words, cooling may be performed even when the electromagnetic field is applied to the sleeve. As a result, the manufactured semi-solid metallic slurry can be immediately used in a subsequent forming process.

[0040] The cooling process may be carried out just prior to a subsequent forming process, and preferably, until a solid fraction of the molten metals is 0.1-0.7, i.e., up to time t_2 of FIG. 1. The molten metals may be cooled at a rate of 0.2-5.0°C/sec. The cooling rate may be 0.2-2.0°C/sec depending on a desired distribution of nuclei and a desired size of particles.

[0041] By using the aforementioned process, a semi-solid metallic slurry containing a predetermined amount of solid fraction can be easily manufactured. The manufactured semi-solid metallic slurry is directly subjected to billet formation process for forming a billet for thixocasting using rapid cooling, or, alternatively, die casting, forging, or pressing process for forming final products.

[0042] As described above, according to the present invention, a semi-solid metallic slurry can be manufactured within a short period of time. That is, manufacturing of a metallic slurry with a solid fraction of 0.1-0.7 occurs within merely 30-60 seconds from loading the molten metals into the sleeve. In addition, the manufactured metallic slurry can be used for forming products having uniform, dense spherical crystalline structures.

[0043] The aforementioned method for manufacturing a semi-solid metallic slurry can be performed using an apparatus according to an embodiment of the present invention as shown in FIGS. 2 and 3.

[0044] Referring to FIG. 2, a semi-solid metallic slurry manufacturing apparatus according to an embodiment of the present invention comprises at least one sleeve 2 for receiving molten metals in liquid state; a stirring unit 1 for applying an electromagnetic field to the molten metals; at least one plunger 5 for defining the bottom of a space where the molten metals are loaded, the plung-

er being inserted into an end of the sleeve; and a driving unit 3 for driving the plunger 5 upward and downward.

[0045] The stirring unit 1 is mounted on the top of a hollow base plate 14. The base plate 14 is supported by a support member 15, installed at a predetermined height from the ground. The coil 11 for applying an electromagnetic field is mounted on the base plate 14, while being supported by a frame 12 having an inner space 13. The coil 11 is electrically connected to a controller (not shown) and applies a predetermined intensity of electromagnetic field toward the space 13 to electromagnetically stir the molten metals contained in the sleeve 2 placed in the space 13. Although not shown in FIG. 2, the stirring unit 1 may be an ultrasonic stirrer.

[0046] As shown in FIG. 2, the sleeve 2 may be placed inside the stirring unit 1, i.e., in the space 13. The sleeve 2 may be fixed on the base plate 14 while in contact with the frame 12. The sleeve 2 may be made of a metallic material or an insulating material. However, it is preferable to use the sleeve 2 made of a material having a higher melting point than the molten metals to be loaded thereinto. The lower end of the sleeve 2 is closed by the plunger 5 and the upper end of the sleeve 2 is open for receiving molten metals. That is, the sleeve 2 may be in the form of a vessel with a bottom defined by the plunger 5. However, there are no particular limitations to the structure of the sleeve 2, provided that the plunger 5 is inserted in the lower part of the sleeve 2. Although not shown in FIG. 2, a thermocouple may be installed in the sleeve 2 while the thermocouple is connected to the controller for providing temperature information to the controller.

[0047] The apparatus of the present invention may further comprise a temperature control element 20 that is installed around the sleeve 2, as shown in FIG. 3. The temperature control element 20 is comprised of a cooler and/or a heater. In the embodiment of FIG. 3, a water jacket 22 acts as the cooler and an electric heating coil 23 acts as the heater. The water jacket 22 is installed around the sleeve 2 and contains a cooling water pipe 21. The electric heating coil 23 is installed around the water jacket 22. The cooling water pipe 21 may be buried in the sleeve 2 and other heating means except for the electric heating coil 23 may be used. There are no particular limitations to the structure of the temperature control element 20, provided that the temperature control element 20 can adjust the temperature of molten metals or slurries. Molten metals contained in the sleeve 2 can be cooled at an appropriate rate using the temperature control element 20. It is understood that such a sleeve 2 can be applied to all of the following embodiments of a semi-solid metallic slurry manufacturing apparatus according to the present invention. Molten metals contained in the sleeve 2 may be cooled using the temperature control element 20 or spontaneously.

[0048] The plunger 5, inserted in the lower part of the sleeve 2, moves upward and downward while connected to the driving unit 3. The lower end of the plunger 5 is connected to a piston rod 51, which is in turn coupled with the driving unit 3.

[0049] The driving unit 3 comprises a driving motor and a gear or a hydraulic cylinder, etc. The driving unit 3 further comprises a power system 31 electrically connected to the controller.

[0050] A loading unit 4 may be used as means for providing molten metals to the sleeve 2. As for the loading unit 4, a general ladle, which is electrically connected to the controller, may be used. In addition, a furnace for forming molten metals may be directly connected to the loading unit 4. Any devices for loading molten metal into the sleeve 2 can be used as the loading unit 4.

[0051] In the embodiment of a semi-solid metallic slurry manufacturing apparatus according to the present invention as shown in FIG. 2, after the driving unit 3 is operated to place the plunger 5 in the lowermost position of the sleeve 2, an electromagnetic field having a predetermined frequency is applied to the interior of the sleeve 2 at a predetermined intensity by the stirring unit 1. Next, metals M that have melted in a separate electrical furnace, are loaded via the loading unit 4 into the sleeve 2 under the electromagnetic field. Applying an electromagnetic field to the sleeve 2 may also be performed simultaneously with or in the middle of loading the molten metals M into the sleeve 2, in addition to prior to the loading, as described above.

[0052] As shown in FIG. 4, after the molten metals are loaded into the sleeve 2, the sleeve 2 is cooled at a predetermined rate until a solid fraction of a resultant semi-solid metallic slurry S is in a range of 0.1-0.7. In this case, the cooling may be carried out at a rate of 0.2-5.0°C/sec, preferably 0.2-2.0°C/sec. As mentioned above, the cooling may be carried out by the temperature control element 20 but is not limited thereto. It is understood that the molten metals contained in the sleeve 2 may be spontaneously cooled without the aid of the temperature control element 20.

[0053] Meanwhile, the application of an electromagnetic field may be sustained until the cooling is completed, i.e., a solid fraction of the resultant semi-solid metallic slurry is in the range of at least 0.001-0.7. In view of the energy efficiency, it is preferable to carry out the application of an electromagnetic field after loading the molten metals into the sleeve 2 until the solid fraction is at least 0.001-0.4, more preferably, 0.001-0.1. The time required for these solid fraction levels can be determined by previous experiments. It is understood that the cooling can be performed during the application of the electromagnetic field, as described above.

[0054] After the slurry S is manufactured, the driving unit 3 is operated to raise the plunger 5, as shown in FIG. 5. Therefore, the slurry S is drawn out from the sleeve 2 and then transferred to an apparatus for a subsequent forming process, such as rheocasting process, by a transfer unit such as a robot.

[0055] The semi-solid metallic slurry manufacturing apparatus of the present invention can continuously

manufacture semi-solid metallic slurries in a large scale and can be readily and conveniently applied to a subsequent process. Therefore, the total process efficiency is improved.

[0056] The apparatus for manufacturing a semi-solid metallic slurry according to the present invention can be used for rheocasting of various kinds of metals and alloys, for example, aluminum, magnesium, zinc, copper, iron, and alloys thereof. Semi-solid metallic slurries manufactured according to the present invention contain spherical microparticles of uniform distribution with an average size of 10-60μ m.

[0057] As apparent from the above description, according to the present invention, uniform, spherical microstructural particles can be obtained. Therefore, mechanical properties for alloys are improved.

[0058] Such uniform spherical particles can be formed within a short time through electromagnetic stirring at a temperature above the liquidus temperature of molten metals to thereby generate more nuclei near inner vessel walls.

[0059] By using a semi-solid metallic slurry manufacturing apparatus according to the present invention, the overall slurry manufacturing process can be simplified, and the duration of electromagnetic stirring and forming time can be greatly shortened, thereby saving energy for the stirring and costs.

[0060] The semi-solid metallic slurry manufacturing apparatus according to the present invention makes it convenient to perform a subsequent process and increases the yield of formed products.

[0061] The apparatus structure is relatively simple and thus a large amount of semi-solid slurries can be rapidly manufactured in a convenient manner.

[0062] While the present invention has been particularly shown and described with reference to exemplary embodiments thereof, it will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the spirit and scope of the present invention as defined by the following claims.

Claims

1. An apparatus for manufacturing a semi-solid metallic slurry, the apparatus comprising:

   at least one sleeve for receiving molten metals in liquid state;
   a stirring unit for applying an electromagnetic field to the molten metals in the sleeve;
   at least one plunger for defining the bottom of a space where the molten metals are loaded, the plunger being inserted into an end of the sleeve; and
   a driving unit for driving the plunger upward and downward.

2. The apparatus according to claim 1, wherein the stirring unit applies the electromagnetic field to the sleeve prior to loading the molten metals into the sleeve.

3. The apparatus according to claim 1, wherein the stirring unit applies the electromagnetic field to the sleeve simultaneously with loading the molten metals into the sleeve.

4. The apparatus according to claim 1, wherein the stirring unit applies the electromagnetic field to the sleeve in the middle of loading the molten metals into the sleeve.

5. The apparatus according to claim 1, wherein the stirring unit applies the electromagnetic field to the sleeve until the loaded molten metals have a solid fraction of 0.001-0.7.

6. The apparatus according to claim 5, wherein the stirring unit applies the electromagnetic field to the sleeve until the loaded molten metals have a solid fraction of 0.001-0.4.

7. The apparatus according to claim 6, wherein the stirring unit applies the electromagnetic field to the sleeve until the loaded molten metals have a solid fraction of 0.001-0.1.

8. The apparatus according to claim 1, wherein the molten metals in the sleeve are cooled until they have a solid fraction of 0.1-0.7.

9. The apparatus according to claim 8, further comprising a temperature control element that is installed around the sleeve to cool the molten metals in the sleeve.

10. The apparatus according to claim 9, wherein the temperature control element comprises at least one of a cooler and a heater that are installed around the sleeve.

11. The apparatus according to claim 9, wherein the temperature control element cools the molten metals in the sleeve at a rate of 0.2-5.0°C/sec.

12. The apparatus according to claim 11, wherein the temperature control element cools the molten metals in the sleeve at a rate of 0.2-2.0°C/sec.

FIG. 1

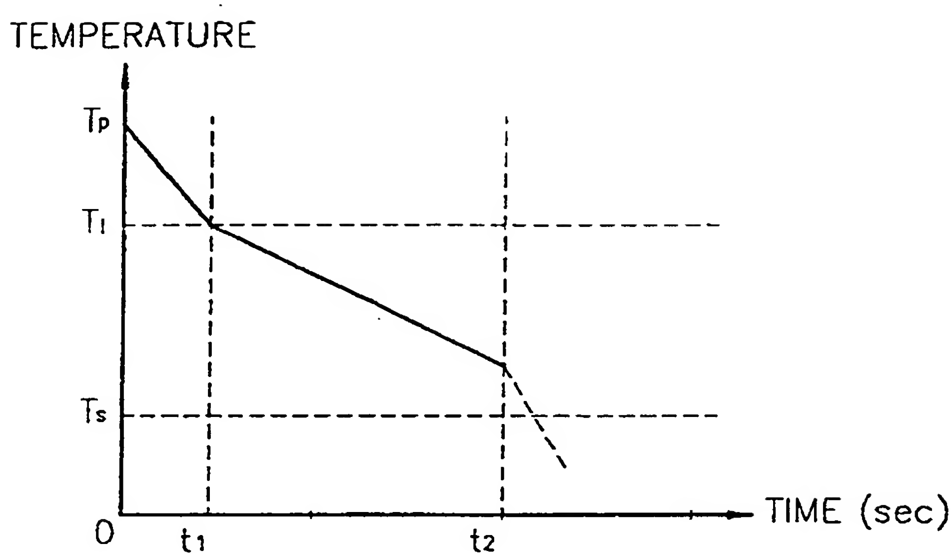


FIG. 2

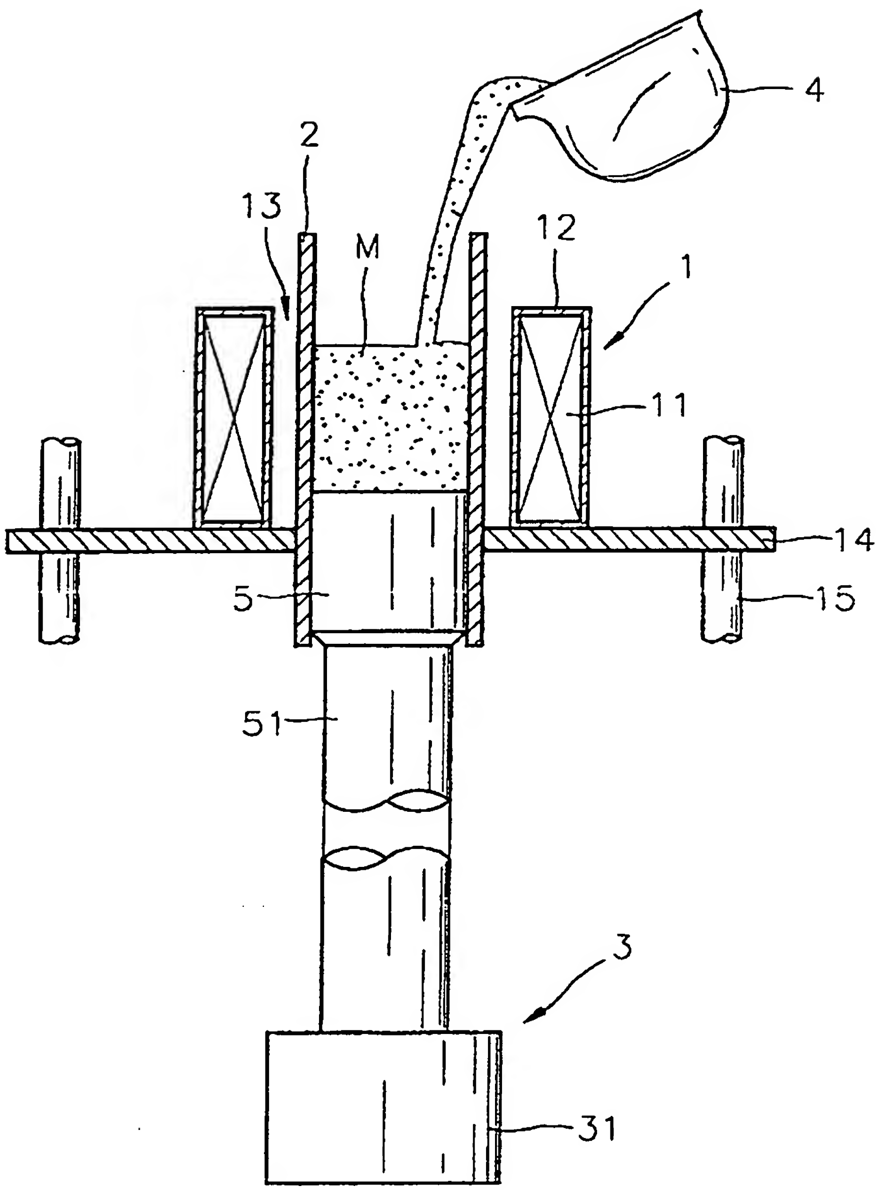


FIG. 3

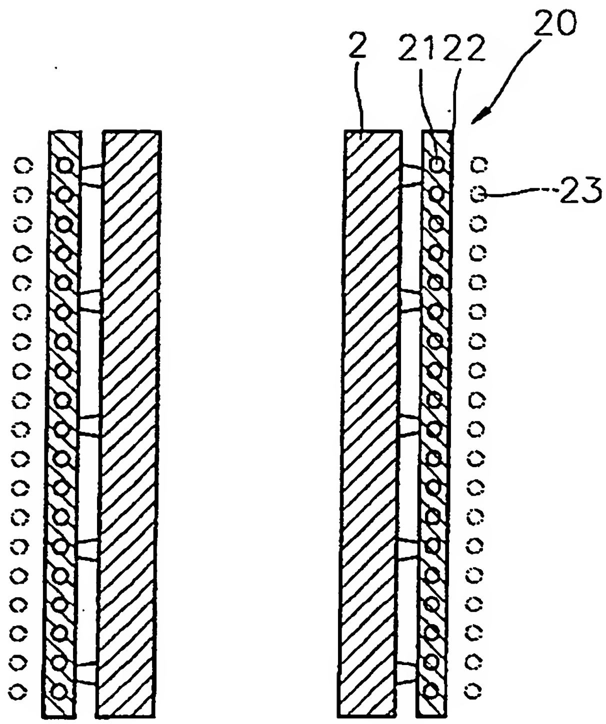


FIG. 4

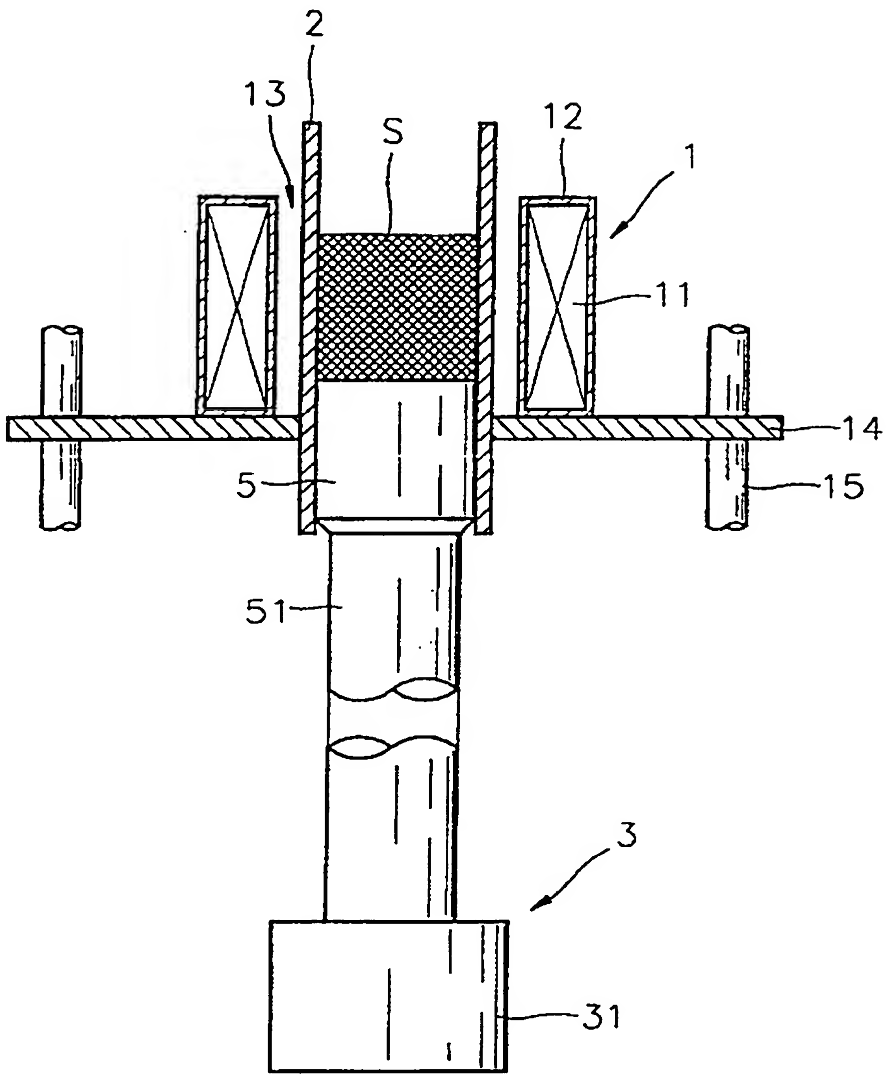
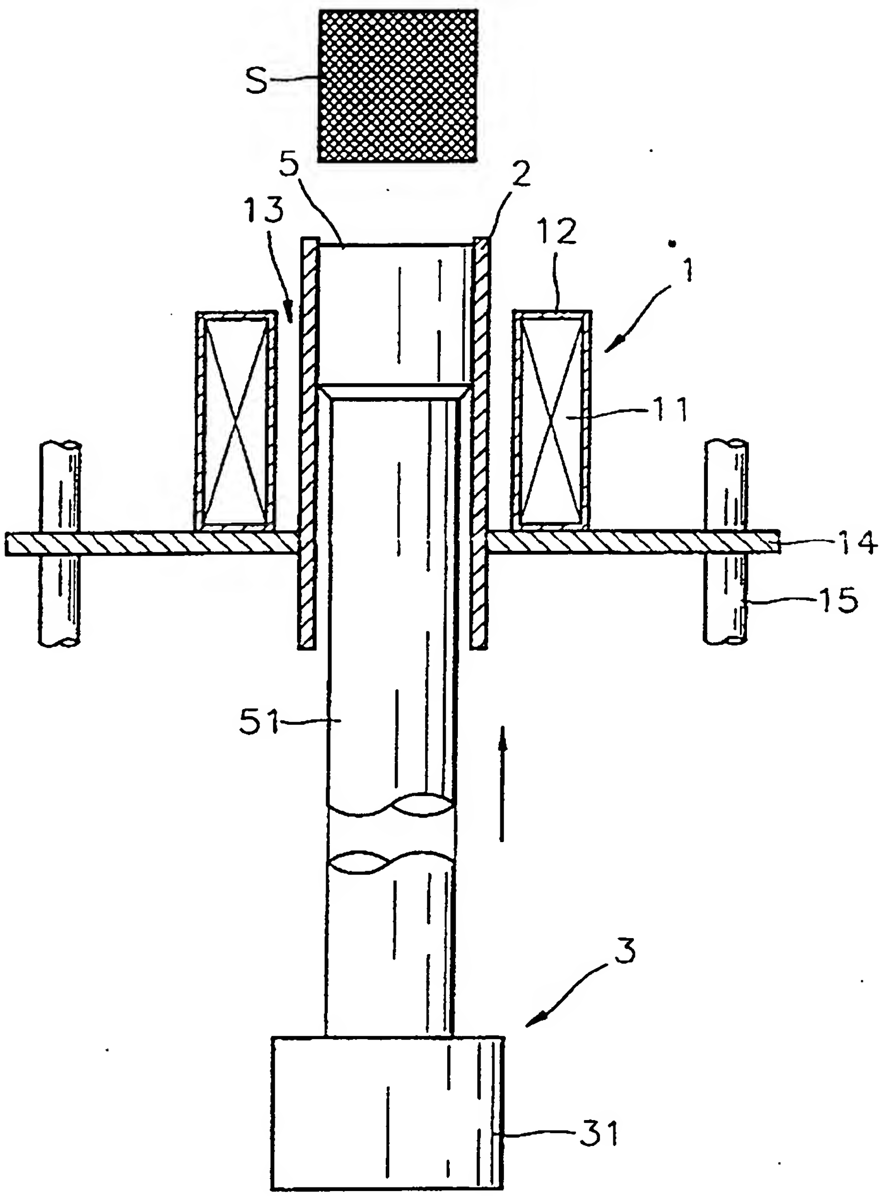


FIG. 5



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PARTIAL EUROPEAN SEARCH REPORT

which under Rule 45 of the European Patent Convention shall be considered, for the purposes of subsequent proceedings, as the European search report

Application Number
EP 03 25 3449

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	EP 0 490 463 A (AMAX INC ;INLAND STEEL CO (US)) 17 June 1992 (1992-06-17) * page 4, line 33 - page 4, line 57; claims 1,11-22,35-38; figures 1-4 * ---	1,9,10	B22D1/00 B22D17/00 B22D11/10 C22C1/00 B22D25/06 B22D27/02
X	US 4 465 118 A (TYLER DEREK E ET AL) 14 August 1984 (1984-08-14) * claims 1,4-7; figure 1 * ---	1,9,10	
X	US 4 450 893 A (TYLER DEREK E ET AL) 29 May 1984 (1984-05-29) * claims 1-3; figures 1,6 * -----	1,9,10	

TECHNICAL FIELDS SEARCHED (Int.Cl.7)

B22D
C22C

INCOMPLETE SEARCH

The Search Division considers that the present application, or one or more of its claims, does/do not comply with the EPC to such an extent that a meaningful search into the state of the art cannot be carried out, or can only be carried out partially, for these claims.

Claims searched completely :

1,9,10

Claims searched incompletely :

Claims not searched :

2-8,11,12

Reason for the limitation of the search:

The subject matter of claims 2-8, 11 and 12 does not relate to apparatus features but to method features. It would also appear that these embodiments are covered by the applicant's published application EP-A-1 405 684.

Place of search	Date of completion of the search	Examiner
MUNICH	7 April 2004	Bergman, L

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 03 25 3449

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

07-04-2004

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EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82